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Gordon L. Shulman and Michael I. Posner

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Relating Sensitivity and Criterion Effects to the Internal Mechanisms of Visual Spatial Attention[1]

Gordon L. Shulman and Michael I. Posner

A recent paper by Muller and Findlay (1987) raises the important issue of how to relate the parameters d' and beta to the internal mechanisms that process visual stimuli. In this commentary we consider the widely held view that d' changes reflect a variety of mechanisms leading to perception, but that beta changes reflect a single high level decision mechanism that is postperceptual and under conscious control. We will argue that in a complex highly parallel, multi-level system, both sensitivity and criterion shifts may influence perception in lawful ways - neither being necessarily more basic and important. Later in the paper, we will also raise some methodological considerations that qualify Muller and Findlay's results.

We do not argue that Muller and Findlay's conclusion that probability manipulations produce beta shifts in detection tasks and d' shifts in identification tasks is necessarily wrong. We do question, however, the implication Muller and Findlay along with others often draw from this kind of result - that detection tasks involve 'radically' different selection mechanisms than identification tasks. In the following discussion, the terms d' and beta will refer to the quantities one computes from data collected in an experiment; the term criterion or signal-noise ratio will refer to the theoretical variables that may underly changes in those measured quantities.

The Standard Interpretation of Beta Shifts

What mechanisms produce a beta shift? The usual answer is that shifts in beta reflect the operation of a conscious high level decision mechanism under the observer's control. It is a mechanism that operates fairly late in processing after stimuli have been encoded. The same mechanism is assumed to operate in all detection tasks, whether one is detecting tones, points of light or tumors. The mechanism uses in a rough sense the rules of statistical decision theory to set criteria, which are therefore influenced by probability manipulations and changes in payoffs. Experiments have confirmed that changes in signal probability or payoffs produce changes in beta.

According to this view, beta shifts in location cueing experiments result from something like the following process. If subjects are cued that a stimulus at a particular location is unlikely, then a percept at that location is disregarded, consciously rejected. Although signal detection theory only speaks of signal and noise levels and criterion values (it is not necessarily intended as a process model) this interpretation of the mechanism producing beta shifts is widespread. It doubtless results from the fact that instructing subjects to change their willingness to report a signal produces measured shifts in beta. The assumption seems to be that since beta shifts in this case are caused by a

particular mechanism, any shift in beta must be caused by the same mechanism.

Empirical Problems for the Standard Interpretation of Beta Shifts

Psychologists often ascribe d' shifts produced by different variables to different mechanisms (Kahneman, 1973). For example, luminance masks interfere with target identification only when target and mask are presented to the same eye, while pattern masks are effective under dichoptic presentation (Turvey, 1973). These results have suggested a distinction between central and peripheral masking. Changes in stimulus duration or other temporal variables produce different effects on detection depending upon the spatial frequency of the target stimulus (Tolhurst, 1975a, 1975b; Legge, 1978). These latter effects are attributed to the different spatial and temporal properties of sustained and transient mechanisms.

The recognition that changes in d' may be caused by different mechanisms is fortunate. Given that there are two basic parameters in signal detection theory, assigning each parameter to a particular mechanism would produce limited two box theories of a system which is a much more complicated multi-level affair. However, our interpretations of beta are more restricted (but see Kahneman, 1973). This may partly result from parsimony. If only a single mechanism is required to account for beta changes, there is no reason to postulate multiple mechanisms. We will argue below that the literature on spatial attention cannot be explained in terms of the decision mechanism commonly assumed to underlie beta shifts; i.e. the mechanism that produces beta shifts when subjects are instructed to change their willingness to report a signal.

This literature generally uses simple reaction time rather than detection, but as Shaw (1984) and Duncan (1980) have noted, the same decision framework is applicable. When the decision criterion is lowered for a location, it takes less time for a stimulus to exceed that criterion, resulting in a faster response.

A number of observations from location cueing experiments indicate constraints on performance that are inconsistent with the operation of the standard decision mechanism.

1. The performance deficit for noncued locations is greater if those locations cross either the vertical or horizontal meridians relative to the cued location (Hughes & Zimba, 1987; Rizzolatti, Riggio, Descola & Umilta, 1987). Further, deficits for uncued locations are a function of the distance/number of intervening positions of the uncued location from the cued location (Downing & Pinker, 1985; Shulman, Wilson & Sheehy, 1985; Shulman, Sheehy & Wilson, 1986; Rizzolatti, et. al., 1987; Hughes & Zimba, 1987, argue that this effect depends upon the use of an articulated visual field). Distance effects have also been reported for the effects of distractors in identification tasks

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(Eriksen & St. James, 1986) and for probe tasks in which the target occurs at different distances from a second stimulus that the subject is processing or has just processed (LaBerge, 1983; Sagi & Julesz, 1986)). Moreover, the slope of the distance function decreases with the eccentricity of the cue. This latter result has also been found using both probability manipulations (Downing & Pinker, 1985; Shulman, Wilson & Sheehy, 1985; Shulman, Sheehy & Wilson, 1986) and probe methods (Sagi & Julesz, 1986). Why should a decision maker raise criteria for noncued locations to a degree dependent on the distance from the cued location and why should these changes depend on eccentricity? Why should a decision maker care whether the uncued stimulus crosses the vertical or horizontal meridians?

2. In some situations, probability effects are weaker if the same location is made highly probable over a long block of trials, rather than being cued on each trial (Posner, et. al., 1980). Blocked conditions would seem ideal for the standard decision criterion mechanism.

3. Without any manipulation of probability similar changes in performance can be obtained in both detection and identification tasks by presenting a peripheral stimulus near the target (Jonides, 1976, 1980; Maylor, 1985), or by having a target occur near a task being performed by the subject (Laberge, 1983; Hoffman, Nelson & Houck, 1983; Sagi and Julesz, 1986). If a peripheral stimulus is a target for an eye movement, facilitation is also found at the target location prior to the actual movement (Posner, 1980; Remington, 1980; Shepard, Findlay & Hockey, 1985).

It is not known if these non-probabilistic methods produce beta or d' shifts during detection tasks. But suppose they produce beta shifts. Why would the decision maker be forced to attend to the location of a projected eye movement even when a foveal target is given a higher probability? This kind of constraint is clearly outside of the characteristics usually given to an ideal observer. However, it is consistent with the operation of a spatial selection mechanism.

Nor does it seem reasonable to take the view that probability manipulations involve the standard decision process while peripheral cues and eye movements affect performance via some other mechanism. If a peripheral cue is presented or an eye movement is prepared to a location with a low target probability, that location will initially be facilitated in comparison with higher probability locations. Probabilistic and non-probabilistic manipulations direct the orientation of a single selection mechanism (Posner, 1980; Posner & Rafal, 1982; Shepard, Findlay & Hockey, 1985; For a possible dissociation of these two manipulations, see Briand & Klein, 1987).

4. Patients with lesions of the parietal lobe show characteristic performance shifts in reporting targets in the field contralesional to

the cued location (Baynes, Holtzman & Volpe, 1986; Ladavas, 1987; Morrow & Ratcliff, 1987, Posner, et. al., 1984). These impairments are not due to a failure to understand the task or to a problem in sensory input or motor output (Posner, et al, 1984). Subjects show they can respond to probability manipulations when targets are in the ipsilesional field. To the extent that these cueing deficits represent a malfunction of a decision mechanism, that mechanism must be field specific. Moreover, the effects of lesions can be specific to modalities. De Renzi, Gentilini and Pattacini (1984) have shown statistical independence between visual and auditory deficits (see also Sieroff & Michel, in press), indicating that the decision mechanism is modality specific.

These effects occur in luminance detection (Posner, et. al, 1984), visual search (Friedrich, Walker & Posner, 1980) and identification tasks (Riddoch & Humphreys, 1987). There is no evidence that patients show a basic difference between detection and identification.

In (1) and (2) criteria shifts resulting from cueing manipulations are based on rules that are not derived from the theory of the ideal detector. The non-probability manipulations of (3) also cannot be explained through standard decision rules, and as noted, they probably affect the same mechanism as probability cues. One could say that the mechanism of the standard theory incorporates rules, in addition to those originally envisioned, but we are then left without a theory explaining why the system follows these extra rules. Moreover, the field and modality specificity of the lesion results (4) suggest a much different mechanism than that thought to be responsible for beta shifts.

Alternative Mechanisms for Producing Beta Shifts

The constraints outlined above seem more consistent with a selective attention system than the standard decision mechanism. While we do not intend to develop a theory of selective attention, consider a simple selection mechanism that governs whether information is transmitted from one process to another; for example in detection tasks, from sensory pathways to those involved in making decisions and responses. Selection might be accomplished by only passing activity that exceeds a certain criterion value. When one cues a certain region that value is lowered, increasing the likelihood that noise generated activity and signal generated activity will be passed to other systems. If these later systems do not change signal/noise ratios, a beta shift will result. Alternately, a colleague has suggested that overall activity is boosted at cued locations. Since this increase will occur for both signal and noise, the effect is again equivalent to shifting a criterion.

Kahneman (1973) has noted that a criterion at one level of the system essentially controls what categorizations are made at that level and therefore, what information is passed to the next. In the standard signal detection model, the criterion controls the categories 'yes' and 'no' and

therefore the information sent to an overt response stage. In the present model, a criterion controls a selection process that determines whether information from different spatial regions is input to other processing stages. This criterion shift may have powerful perceptual consequences since a categorization at one stage can affect processing at a subsequent stage. For example, Kahneman notes that the rectangular perception of the Ames room results from a criterion bias since a trapezoidal interpretation is equally consistent with the sensory input. Yet the categorization or description of the Ames room as rectangular produces a very powerful effect on size perception. Effects of expectations or top-down processing on perception can be treated similarly (Broadbent, 1971). Since a criterion controls the flow of information from one process to another, the function or effect of the criterion shift will depend on the nature of these processes.

Spatial selection, for example, may serve a number of functions or produce a variety of effects depending on the task. Selection may determine which stimuli engage an eye movement control system. Several papers have shown that a preparatory shift of attention precedes an eye movement to a peripheral stimulus (Remington, 1980; Shepard, Findlay & Hockey, 1986). If the task involves identification or conjunctive search, spatial selection may enable analyzers limited in capacity to process the relevant stimulus without suffering interference. Other authors have proposed additional reasons for spatial selection (Ullman, 1984; Navon, 1985).

Reconsider Muller and Findlay's argument that a radically different mechanism operates in detection and identification tasks. The above discussion suggests the alternative possibility that the selection mechanism is the same in all of these paradigms. The task dependency would reflect how the stimuli are processed once they are selected. To the extent that selection controls access to mechanism that change signal/noise ratios, selection will produce d' changes. In the case of detection, signal/noise ratios are determined early in the system, prior to selection. Selection therefore produces a beta shift. In the case of identification, many processes will determine the final signal/noise ratio; some of the relevant processes may well occur subsequent to selection. Selection therefore produces a d' shift.

When subjects are cued that a stimulus will occur at a location, introspectively, one has the strong impression of attending to that location. This impression does not depend on what stimuli are subsequently presented, i.e. whether it is a single stimulus in an empty field (detection), or four stimuli (identification). Although completely different mechanisms may underlie the performance consequences of using the cue, it seems likely that the same mechanism is involved.

Methodological issues in Muller & Findlay's Experiment

Aside from our concern over the interpretation of Muller and Findlay's results, we believe there may be problems with their methodology. Muller and Findlay make two specific claims in their article.

1. Probability manipulations produce beta shifts in detection tasks and d' shifts in identification tasks. Muller and Findlay suggest that the selection process in detection tasks is radically different than in identification tasks. In identification tasks, the probability manipulation directs a selection process that determines which inputs are analyzed by limited capacity form analyzers. In detection tasks, the probability manipulation does not affect this selection mechanism, or if it does, the selection mechanism has no effect on performance (either d' or beta). Observers use the location probabilities to affect a quite different mechanism, a decision process that differentially weights evidence from different regions.

Muller and Findlay's conclusion concerning the effect of location probability manipulations on d' and beta during detection tasks rests on a particular procedure for assigning false alarms to the different validity conditions. When a subject makes a false alarm it is not possible to assign that observation to a particular location since no signal was in fact presented. Muller and Findlay adopt Bashinski and Bachrach's method of asking the subject to make a location response and using that response to assign false alarms to valid and invalid conditions. Subjects in Muller and Findlay's experiment make three responses on each trial. First, they give a yes-no response, then a confidence rating of the response, and finally, a location response. Muller and Findlay suggest that these responses are determined as follows. On any trial, strength values for the four possible locations are sampled. These samples are then weighted according to the apriori probabilities assigned to their location. If the sum of the weighted samples exceeds a criterion, a detection response is given. Different degrees of confidence essentially correspond to different degrees of (weighted) strength with respect to the yes-no criterion (equivalently, criterion are set up for each confidence level). The location response is determined by the location of the weighted sample giving the largest strength response.

This account makes a number of assumptions. During the detection process, the observer must know the location of each sample so that its strength can be appropriately weighted. This knowledge must then be reflected in the location response so that the latter is an accurate measure of the use of location information and location probabilities in the detection process.

Suppose there was some uncertainty during the detection stage concerning the location of the sample being weighted. For weak signals, subjects may know that something was presented, but may not know where, a dissociation that could depend upon signal strength. Uncertainty

concerning sample location will decrease the effect of the probability manipulation on detection; valid samples will receive their stronger weighting on fewer trials. The same uncertainty, however, will increase the effect of the probability manipulation on the location response. With more uncertainty concerning the actual location of the strongest sample, subjects will rely more on apriori probabilities. Imperfect knowledge of location will therefore increase the estimated false alarm rate for the valid condition.

Although imperfect knowledge of location could arise during the initial perceptual stage, later processes might also contribute. Since the location response is the third response the subject makes, the subject may forget where the stimulus was presented, particularly when the initial signal is weak and ambiguous. Any loss of location information between the detection and location response will again increase the effect of the apriori location probabilities or the location response.

This analysis suggests that an estimate of the false alarm rate based on the location response will inflate the 'true' false alarm rate for valid trials. In the luminance detection condition of Experiment 2 of Muller and Findlay, the false alarm rate was 7.2% for valid trials, 4.8% for invalid. This small increase might well be accounted for by the factors suggested above.

Given the complexities and assumptions involved in the method of Muller and Findlay, the issue of d' shifts and spatial attention is perhaps best addressed using 'criterion free' methods such as two interval forced choice.

We therefore do not believe that Muller and Findlay have convincingly demonstrated that cueing produces d' shifts in identification tasks and beta shifts in detection tasks. However, even if this result were established, as noted above, we question their interpretation of the underlying mechanisms.

2. Spatial attention can be divided between different locations contrary to the conclusion of Posner, Snyder & Davidson (1980).

We do not see how Findlay and Muller's experiment contradicts the results of Posner et. al. The latter authors were concerned with whether attention could be split to disparate locations. They used a linear display of four locations, and showed that when a location was cued with high validity, a secondary cue with lower validity affected cue performance if it was directed to an adjacent location but not if it was directed to a location that was separated by an intervening location from the primary cue location.

The data of Posner, et. al. show that attention can be spread to multiple adjacent locations but not to locations separated by noncued positions. Kiefer and Siple (1987, in press) has recently replicated both

results using a trial by trial technique in which two equally probable locations were used. and other authors using different methods have confirmed that attention can be spread over regions of variable size (LaBerge, 1983; Eriksen & St. James, 1986).

Muller and Findlay used a display in which targets could appear at one of four points on an imaginary square. Subjects were never required to attend to regions separated by noncued regions. Trials in which two locations were cued can be grouped into three categories 1) both cued positions in the left and right field, 2) both in the upper or lower field, and 3) both along the diagonal of the square. In the first two cases, subjects could use the cue by spreading attention to adjacent regions. The third case is somewhat ambiguous but does not require the spatial distribution of attention that Posner et. al. studied. Muller and Findlay's experiment is therefore consistent with Posner et. al.'s claim that attention can be spread to adjacent regions; it does not pertain to the claim that it cannot be split (at least in the sense Posner et. al. studied).

Currently, the study of attention is entering an exciting phase in which the operations involved in internal mechanisms of attention are being related to neural systems (see Berlucchi & Rizzolatti, 1987; Posner & Marin, 1985 for reviews). These efforts require combining careful performance studies of the type done by Muller & Findlay with efforts to understand the neural systems involved. For these efforts to succeed, it is necessary to relate performance parameters (e.g. d' and beta) to the many mechanisms that may influence them.

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References

Baynes, K., Holtzman, J.D. & Volpe, B.T. (1986) Components of visual attention: alterations in response pattern to visual stimuli following parietal lobe infarction. Brain, 109, 99-114.

Berlucchi, G. & Rizzolatti, G. (eds.) (1987) Selective visual attention. Neuropsychologia, 25, 1A.

Briand, K. & Klein, R. (1987) Is Posner's "beam" the same as Treisman's "glue": On the relation between visual orienting and feature integration theory. JEP:HPP, 13, 228-241.

Broadbent, D. (1971) Decision and Stress. London:Academic Press.

De Renzi, E., Gentilini, M. & Pattacini, F. Auditory extinction following hemisphere damage. Neuropsychologia, 1984, 22, 733-744.

Downing, C. and Pinker, S. (1985) The spatial structure of visual attention. In Mechanisms of Attention: Attention and Performance XI, M. I. Posner and O.S.M. Marin (eds.). Erlbaum and Associates, Hillsdale, New Jersey.

Duncan, J. (1980) The demonstration of capacity limitation. Cognitive Psychology, 12, 75-96.

Eriksen, C. and St. James, J. (1986) Visual attention with and around the field of focal attention: a zoom lens model. Perception & Psychophysics, 40, 225-240.

Friedrich, F.J., Walker, J. & Posner, M.I. (1985) Effects of parietal lesions on visual matching: implications for reading errors. Cognitive Neuropsychology, 2, 253-264.

Hoffman, J., Nelson, B. & Houck, M. (1983) The role of attentional resources in automatic detection. Cognitive Psychology, 15, 379-410.

Hughes, H. & Zimba, L. (1987) Natural boundaries for the spatial spread of directed visual attention. Neuropsychologia, 25, 5-18.

Jonides, J. (1976) Voluntary versus reflexive control of the mind's eye movement. Paper presented at the Psychonomics Society, St. Louis, MO.

Kahneman, D. (1973) Attention and Effort. Englewood, NJ:Prentice-Hall.

Kiefer, R.J. & Siple, P. (1987) Spatial constraints on the voluntary control of attention across visual space. Canadian Journal of Psychology, 41, 474-489.

LaBerge, D. (1983) Spatial extent of attention to letters and words. Journal of Experimental Psychology: Human Perception and Performance, 9, 371-380.

Ladavas, E. (1987) Is the hemispatial deficit produced by right parietal lesions associated with retinal or gravitational coordinates? Brain, 167-180.

Legge, G. (1978) Sustained and transient mechanisms in human vision: temporal and spatial properties. Vision Research, 18, 69-81.

Maylor, E. (1985) Facilitatory and inhibitory components of orienting in visual space. In M. Posner and O. Marin (eds.) Attention and Performance XI. Hillsdale, NJ:Erlbaum.

Morrow, L.A. & Ratcliff, G. (1987) Attentional mechanisms in visual neglect. J. of Clinical and Experimental Neuropsychology, 9, 1, 74-75.

Muller, H. and Findlay, J. (1987) Sensitivity and criterion effects in the spatial cueing of visual attention. Perception & Psychophysics, 42, 383-399.

Navon, D. (1985) Attention division or attention sharing? In M. Posner and O. Marin (eds). Attention and Performance XI. Hillsdale,NJ:Erlbaum.

Nissen, M., Posner, M. & Snyder, C. (1978) Relationship between attention shifts and saccadic eye movements. Paper presented at the Psychonomics Society, November, 1978.

Posner, M.I. (1980) Orienting of attention. Quarterly J. of Experimental Psychology, 32, 3-25.

Posner, M.I. & Marin, O.S.M. (eds) (1985) Attention and Performance XI. Hillsdale, N.J.:Erlbaum.

Posner, M.I., Snyder, C. & Davidson, B. (1980) Attention and the detection of signals. Journal of Experimental Psychology: General, 109, 160-174.

Posner, M.I., Cohen, Y., and Rafal, R.D. Neural systems control of spatial orienting. Proceedings of the Royal Society of London B 298, 1982, 187-198.

Posner, M.I., Walker, J., Friedrich, F. & Rafal, R. (1984) Effects of parietal injury on covert orienting of attention. Journal of Neuroscience, 4, 1863-1874.

Remington, R. (1980) Attention and saccadic eye movements. Journal of Experimental Psychology:Human Perception and Performance, 6, 726-744.

Riddoch, J. & Humphreys, G.W. (1987) Perceptual and action systems in unilateral visual neglect. In M. Jeannerod (ed.) Neurophysiological and Neuropsychological Aspects of Spatial Neglect, Elsevier:Amsterdam, 151-181.

Rizzolatti, G., Riggio, L., Dascola, I., & Umilta, C. (1987) Reorienting attention across the horizontal and vertical meridians: evidence in favor of a premotor theory of attention. Neuropsychologia, 25, 31-40.

Sagi, D. & Julesz, B. (1986) Enhanced detection in the aperture of focal attention during simple discrimination tasks. Nature, 321, 693-695.

Shaw, M. (1984) Division of attention among spatial locations: a fundamental difference between detection of letters and detection of luminance increments. In H. Bouma and D. Bowhuis (eds.) Attention and Performance X, Hillsdale,NJ:Erlbaum.

Shepard, M., Findlay, J. & Hockey, R. (1986) The relationship between eye movements and spatial attention. Quarterly Journal of Experimental Psychology, 38a, 475-491.

Shulman, G., Wilson, J. & Sheehy, J. (1985) Spatial determinants of the distribution of attention. Perception & Psychophysics, 37, 59-66.

Shulman, G., Sheehy, J. & Wilson, J. (1986) Gradients of spatial attention. Acta Psychologia, 61, 167-181.

Sieroff, E. & Michel, F. (1987) Verbal visual extinction in right/left hemisphere patients and the problems of lexical access. Neuropsychologia, in press.

Tolhurst, D. (1975a) Reaction times in the detection of gratings by human observers: a probabilistic mechanism. Vision Research, 15, 1143-1150.

Tolhurst, D. (1975b) Sustained and transient channels in human vision. Vision Research, 15, 1151-1155.

Turvey, M. (1973) On peripheral and central processes in vision: inferences from an information-processing analysis of masking with patterned stimuli. Psychological Review, 80, 1-52.

Ullman, S. (1984) Visual Routines. Cognition, 18, 97-159.

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